The Mygoora Local Fauna: a late Quaternary vertebrate assemblage from central Australia

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ABSTRACT

The Mygoora Local Fauna (new name) from Mygoora Lake, central Australia (southern Northern Territory), consists of the fossilised remains of 12 vertebrate species referrable to modern taxa. The assemblage includes eight marsupials (*Bettongia lesueur, Dasycercus cristicauda, Dasyurus geoffroii, Lagorchestes hirsutus, Lasiorhinus* cf. *latifrons, Macropus rufus, Macrotis lagotis,* and *Sarcophilus harrisii*), two rodents (*Notomys alexis* and *Rattus villosissimus*), and two reptiles (*Varanus* sp. and a pythonid, ?*Bothrochilus* sp.). *Lasiorhinus* sp. (hairy-nosed wombat) is a first record of the genus in the Northern Territory, while *Sarcophilus harrisii* (Tasmanian devil) is a first record for central Australia, both records representing extensions of prehistoric ranges for these species. Four species (*Bettongia lesueur, Dasyurus geoffroii, Lagorchestes hirsutus* and *Macrotis lagotis*) became regionally extinct in historical times. The fauna is dominated by fossorial species, or species known to occupy existing burrows, that are typical of the Australian arid biogeographic zone. Articulated skeletal remains were preserved in burrows dug into stabilised aeolian sand, with subsequent deflation resulting in localised concentrations of durable fragments at the present land surface. An optically stimulated luminescence (OSL) date of the host aeolian sand provides a maximum age of between 12.1±0.5 and 9.3±0.6 ka for the assemblage. A minimum age could not be determined, but biochronological data suggest that the fauna is possibly of latest Pleistocene or early Holocene age.

KEYWORDS: Mygoora Local Fauna, Northern Territory, Australia, late Quaternary, marsupials, rodents, reptiles, *Sarcophilus, Lasiorhinus*, new records, optically stimulated luminescence date.

INTRODUCTION

Mineralised vertebrate remains were found in 1998 at two sites on the western margin of Mygoora Lake, central Australia (Fig. 1) by P.K.L. in the course of botanical surveying. The sites, which are about 1 km apart, are in deflated aeolian dunes near latitude 25°20' S, longitude 132°40' E. Precise positional information is held on file at the Museum and Art Gallery of the Northern Territory (MAGNT), Darwin. Fossils from the more northerly site, distinguished here as Site 2, are here formally designated the type assemblage of the Mygoora Local Fauna (LF).

Based on an analysis of diagnostic (primarily cranial) remains from the type locality, the Mygoora LF is shown to consist of extant species of Varanidae, Boidae, Dasyuridae, Thylacomyidae, Vombatidae, Potoroidae, Macropodidae and Muridae. The type assemblage, whose geological age is constrained by optically stimulated luminescence (OSL) dating and biochronological considerations to the late Quaternary (probably latest Pleistocene or early Holocene), adds to knowledge of the late Quaternary history of the central Australian fauna (e.g. Copley *et al.* 1989, Baynes and Baird 1992, Baynes and Johnson 1996).

Material from the type locality (Site 2) is held in the MAGNT palaeontological collection under batch number P2663-. Material from Site 1 was scanned to establish whether there were any taxa present that were not also represented at Site 2. None were identified. The Site 1 material, held under batch number P2664-, was not further analysed and is not documented here.

The taxonomy of the Mygoora Lake fossil assemblage was determined by comparison with neontological reference material held in the MAGNT. Because the fauna consists of modern species, no anatomical descriptions are provided. Rather, the fossil assemblage is analysed in terms of its taphonomy and preservational

state, and the ecology and present distributions of represented species. Two species, the Tasmanian devil, *Sarcophilus harrisii* and a hairy-nosed wombat, *Lasiorhinus* sp., are extralimital with respect to their modern distributions. The *Lasiorhinus* is a new record for the Northern Territory. *Sarcophilus harrisii* is depicted in Arnhem Land Aboriginal rock art, and skeletal remains radiocarbon dated at 3120±100 years before present have been found in association with an archaeological deposit just to the west of Arnhem Land (Calaby and White 1966; Calaby and Lewis 1977), but *S. harrisii* has not previously been reported from central Australia.

STRATIGRAPHY AND AGE

Depositional and stratigraphic setting. The following account of the depositional and stratigraphic setting of the Mygoora Lake fossil deposit follows Arakel and Wakelin-King (1991) and Edgoose *et al.* (1993).

Mygoora Lake is a playa in a chain extending 500 km from Lake Hopkins in the central far east of Western Australia, east to the central southern part of the Northern Territory (Fig. 1). The playas define the drainage axis of an un-named elongate Cainozoic sedimentary basin developed upon, and confined by,

folded and fractured Neoproterozoic to Palaeozoic sedimentary rocks of the Amadeus Basin. During the Tertiary, palaeodrainage was into Lake Eyre via the Finke River. Today, however, surface and shallow groundwater flow is internal, with the chain of playas almost completely isolated from the Finke River by aeolian sand.

Tertiary rocks of the Cainozoic basin include valley-fill deposits (coarse sandstone, siltstone and minor marl) and talus and scree, capped by a resistant silcrete duricrust attributed to several episodes of silicification. Siliceous duricrust also formed on exposed Palaeozoic strata, and subsequent dissection has resulted in remnant low mesas and buttes. A veneer of Quaternary aeolian quartz sand, playa deposits, alluvium, calcrete, gypcrete and gypsiferous sand otherwise blankets most of the older strata. Of particular relevance to this report are aeolian sand and calcrete that occur around Mygoora Lake (Fig. 1). The calcrete, mostly obscured by transported sand, resulted from two Late Pleistocene formational episodes, dated by electron spin resonance (ESR) at Curtin Springs, about 90 km west of Mygoora Lake. The earlier phreatic calcrete, dated at 75–34 thousand years (ka) before present, formed beneath the water table along drainage lines, while the later vadose calcrete formed at 27–22 ka by evaporation in groundwater discharge zones, especially at the margins
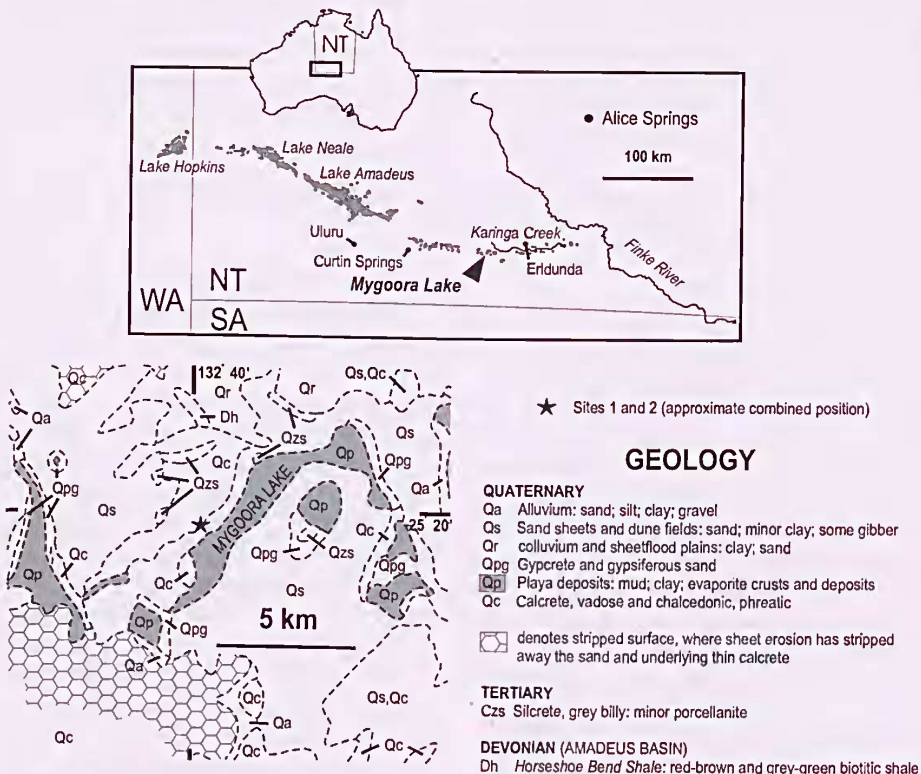

Fig. 1. Locality diagrams and geology of the Mygoora Lake area, taken from the Kulgera SG/53–5 1:250,000 Geological Sheet (Edgoose *et al.* 1993).

Fig. 2. Site 2: **A**, general view of the deflated area producing fossil remains; **B**, surface lag composed of bone fragments (light particles) and rhizoconcretionary clasts (dark particles). **C**, occluded dentition of *Sarcophilus harrisi in situ*. **D**, partially excavated articulated legs of *Bettongia lesueur* found with only the terminal phalanges exposed at the surface. The femur and proximal part of the tibia has partly weathered away. **E**, a second *B. lesueur* skeleton. Note the vertical orientation of the tibia, the broken shaft of which projected to the surface. The skull is to the left. **F**, same specimen as in E after further excavation, showing a rhizoconcretion *in situ*.

of playas. The overlying fine to medium quartz sand, now partly stabilised by vegetation, forms sheets and longitudinal dunes with relief of up to 12 metres. Individual grains are coated by ferruginous clay that imparts the red colour typical of central Australian desert sands. Playa sediments typically consist of brown and green mud containing evaporites (predominantly gypsum), with a crust of halites and other soluble minerals. These muds are derived from the underlying Horseshoe Bend Shale (Devonian) of the Amadeus Basin.

Occurrence of vertebrate fossils. Vertebrate remains were found on deflated dune surfaces (Fig. 2A) at two localities (Sites 1 and 2, Fig. 1) on the western margin of Mygoora Lake. Well-indurated but fragmentary bones rarely more than a couple of centimetres long, and rhizoconcretions, form a surface lag at these sites (Fig. 2B). Amongst the surface fossils there is a preponderance of durable elements such as mammal teeth and jaw fragments. At Site 2, within an area of several hundred square metres, several more complete specimens were found protruding from the surface, and
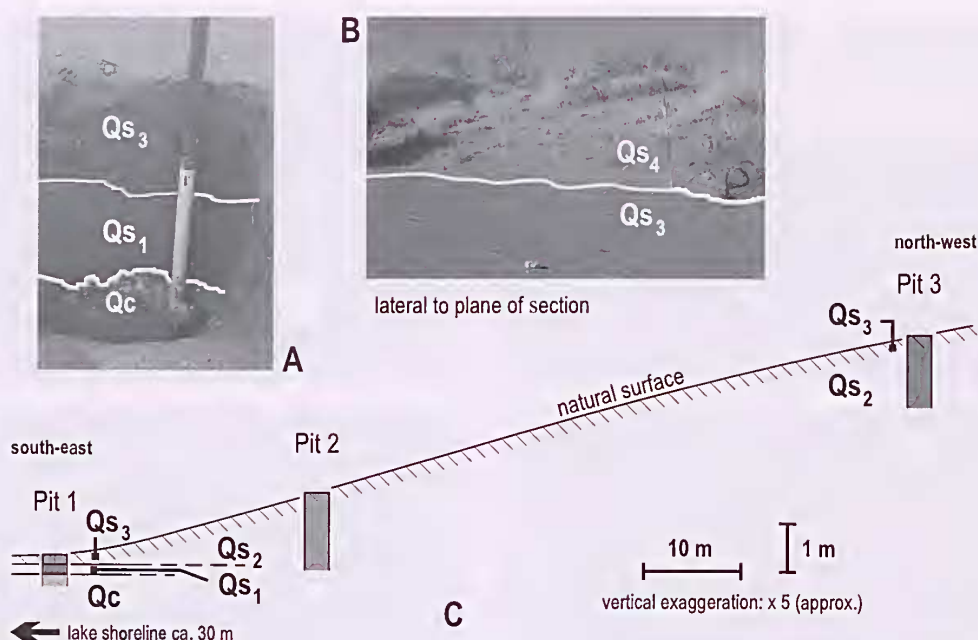
Fig. 3. Summary of stratigraphy at Site 2. **A**, schematic cross-section showing relationships of strata; **B**, stratigraphy in Pit 1; **C**, stratigraphy lateral to the line of section, showing the lighter coloured sand of the active (modern) dune system overlying the older aeolian sands. Qs_{1-4} are informal members of mapping unit Qs of the regional geology (Figure 1; note also Qe), as described in the text.

excavation revealed them to be parts of articulated remains (Figs 2C–F). No such specimens were found at the less extensive Site 1. Some parts of the skeletons excavated at Site 2 had weathered away *in situ*, but other parts are well preserved.

Some exploratory excavation was carried at Site 2 in a search for more articulated skeletons, and, as described below, three shallow stratigraphic pits were also dug. The excavated material was screened to try to ascertain the frequency of rhizoconcretions and skeletal remains within the sediment. However, no additional skeletal material was found in the course of these activities, and rhizoconcretions (Fig. 2F) were found to be very sparse. The indications are that the surface lag (i.e. bone fragments and rhizoconcretions) at both sites have resulted from the deflation of a substantial, but unknown, volume of sediment.

Stratigraphy at Site 2. The stratigraphy at Site 2 is summarised in Figure 3. The local succession consists of carbonate-cemented clayey sand succeeded by red aeolian sand, representing respectively units Qc and Qs of the regional geology (Fig. 1). Qs is here differentiated into four informal members designated Qs_{1-4}. The two lowest stratigraphic units, Qc and Qs_1, were intersected only in Pit 1.

Qc (Figs 3, 4A) consists of hard, carbonate-cemented sandstone, mottled very pale orange (10YR 8/2), greyish orange (10YR 7/4), light brown (5YR 6/4) and moderate brown (5YR 4/4). Only the top 200 mm of the unit was intersected in Pit 1. The sand

fraction is predominantly quartz, with calcrete clasts, feldspar grains, lithic quartz and an opaque mineral (?magnetite) as minor constituents. The sand grains are poorly sorted (very fine to coarse), and range from angular to well rounded. Quartz grains are commonly embayed and/or etched, and are rimmed by goethite that is thicker over embayments in the grains. Primary porosity is filled with micrite with ferruginous and clay inclusions. No sedimentary structures or fossils were observed. The poor sorting, coarse texture, presence of angular grains, and compositional range suggest that the sediment represents localised alluvial reworking of older beds, diagenetically cemented by calcium carbonate and iron compounds. Qc is succeeded in Pit 1 by Qs_1 (fine, red sand) across a sharp, irregular contact representing an erosional unconformity.

Qs_1 is a thin (200 mm) bed of weakly consolidated, massive, unfossiliferous, reddish brown (between moderate reddish brown 10R 4/6 and light brown 5YR 5/6), well-sorted, fine quartz sand. This unit was only recognised in Pit 1, and its extent is not known (Fig. 3). Grains are sub-rounded to rounded and rimmed by goethite, characteristic of 'red' aeolian sands of central Australia. Highly localised void-filling iron compounds (Fig. 4B, inset) may account for both the incipient state of lithification, and the redder hue compared to the next two units (Qs_2/Qs_3) of the succession.

In Pit 1, Qs_1 is succeeded by Qs_3 across an irregular, erosional contact (Fig. 3). The unconformable succession across this contact is supported by

geochronological evidence presented below. Qs_3 is a light brown (5YR 5/6), fine quartz sand, texturally indistinguishable from Qs_1 (compare Fig. 4B and 4C), containing rhizoconcretions and vertebrate remains (Fig. 2). In Pits 2 and 3, on the other hand, the rhizoconcretionary horizon is underlain by apparently barren sand of identical colour which is here distinguished as Qs_2. As discussed below, Qs_2 and Qs_3 are considered to be the same depositional unit, with the latter representing a pedogenic horizon related to an ancient land surface. The transition from Qs_2 to Qs_3 is indistinct.

The stratigraphic succession at Mygoora Lake culminates in Qs_4, the unconsolidated, lighter coloured (moderate reddish orange, close to 10R6/6) fine sand of the modern dune system (Fig. 3).

Geochronology. Two samples, one each from units Qs_1 (field identification ML1) and Qs_3 (ML2) were collected from Pit 1 for dating by optically stimulated luminescence, which was carried out by Drs J.R. Prescott and F.M. Williams at the Department of Physics and Mathematical Sciences, Adelaide University. Methods and results presented below are as reported by J.R. Prescott (written comm., 7 April, 2000: sample laboratory codes AdGL00001 and AdGL00002): comments by Dr Prescott in the Results section pertaining to the possible geological history of the samples are reviewed in the Discussion that follows.

Methods. Ages were determined using green light stimulation of quartz grains in the size range 90–125 mm. Quartz grains of this size were separated using standard techniques (Huntley *et al.* 1993). Equivalent doses were obtained using the Australian Slide method (Prescott *et al.* 1993), and total dose rates were obtained using thick source alpha counting (U and Th) and X-ray fluorescence spectrometry (K). These laboratory methods give a reasonable measurement of the dose rate, though field scintillometry at the time of sampling is desirable in addition. Cosmic ray dose rates were determined from the relationship between depth, density and cosmic ray penetration established by Prescott and Hutton (1994).

Results. Ages were calculated using Grün's AGE programme (commercial, version 1999) and are shown, together with relevant data, in Table 1. Major element analyses obtained by X-ray fluorescence spectrometry are also included.

In determining total dose rates, an allowance must be made for the water content of the material as water absorbs part of the radiation that that would otherwise reach the grains. This poses a problem when dealing with lake sediments (see discussion below) as the lake was presumably full and the sediment saturated at the time of deposition. The water content would subsequently vary with time as the lake dried out. We have therefore provided age determinations for two extremes of water content: saturation and present day content. It is evident from Table 1A that this introduces a considerable uncertainty in the ages. [Sample ML1 (= unit Qs_1): 32.0±2.8 – 24.0±2.1 ka. Sample ML2 (= unit Qs_3): 12.1±0.5 – 9.3±0.6 ka].

Discussion. The poor sorting and presence of large clasts (up to coarse sand grade in thin-section) in Qc is consistent with alluvial deposition, with the micritic clasts probably representing reworked calcrete. The Qc bed was not dated, but its minimum age is constrained to 32.0±2.8 – 24.0±2.1 ka by the overlying unit, Qs_1. The calcrete clasts may be attributable to the regional, phreatic calcrete formation-event of 75–34 ka, while induration of the unit by carbonate cementation may be attributable to the vadose formation-event of 27–22 ka identified by Edgoose *et al.* (1993) and Arakel and Wakelin-King (1991). Petrography and geochronological attributes of the unit are concordant with unit Qc of the regional geology.

All members of Qs at Mygoora Lake have the textural attributes of aeolian sand. As described above, the oldest member at Mygoora Lake, Qs_1, is weakly consolidated, in contrast to the younger units. Units Qs_1 and Qs_3 produced very similar compositional
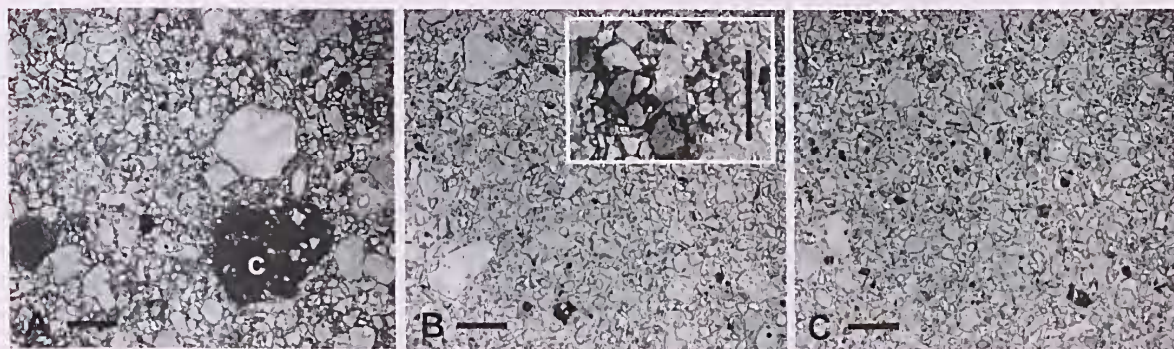

Fig. 4. Photomicrographs of samples from Pit 1; all plane polarised light; scale bars = 1 mm. A, unit Qc (thin section TS 0526), coarse, carbonate-cemented, mottled sandstone; reworked calcrete clast labelled 'c'. B, Qs_1 (TS 0527), weakly-consolidated, fine, red sand. INSET (TS 0528) – zones of iron enrichment (cementation) may account for the incipient lithification of the unit, and deeper red colour compared to the texturally-identical overlying unit, Qs_3. C, Qs3 (TS 0529), fine red sand of the fossiliferous unit.

Table 1. Optically stimulated luminescence and geochemical analyses. A, relevant measurements, dose rates and ages. [1]It was noted during preparation that the material contains a large amount of clay. This would account for the high overall potassium content. [2] Expressed as % dry weight. B, major element analyses obtained by X-ray fluorescence spectrometry. Samples were dried at 110° C for ~2 hours (not pre-ignited), then weighed with a flux and fused to form glass discs. The difference from 100% in the total is the loss on fusion. K_2O values provided to 3 decimal places, but significant to only 2. (J.R. Prescott, written comm. 7 April, 2000)

A

Sample (Laboratory code)	Th content (ppm)	U content (ppm)	K content[1] (%)	Cosmic radiation $(Gy.ka^{-1})$	H_2O content[2] (p) present day (s) saturation	Total dose rate $(Gy.ka^{-1})$ (p) present day H_2O (s) saturation H_2O	Equivalent dose (Gy)	Age (ka) (p) present day saturation (s) saturation
ML1 (AdGL00001)	7.21±0.35	0.72±0.03	1.81±0.05	0.150±0.020	(p) 4.3±1.0 (s) 36.0±2.0	(p) 2.50±0.07 (s) 1.87±0.05	60.0±5.0	(p) 24.0±2.1 (s) 32.0±2.8
ML2 (AdGL00002)	6.32±0.20	0.53±0.02	1.78±0.00	0.160±0.020	(p) 3.1±1.0 (s) 32.0±2.0	(p) 2.41±0.04 (s) 1.84±0.04	22.3±1.1	(p) 9.3±0.5 (s) 12.1±0.6

B

Sample	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	SO_3	LOI %	Total %
ML1	87.36	4.88	2.26	0.04	0.46	0.20	0.40	2.185	0.58	0.03	0.00	0.00	98.40
ML2	87.82	4.38	2.01	0.04	0.25	0.72	0.41	2.145	0.56	0.05	0.01	0.00	98.40

analyses (Table 1B). The only factor that can be identified as possibly accounting for the contrasting mechanical properties is the slightly higher iron content of Qs_1 compared to Qs_3, which is also reflected in the redder hue of Qs_1: quartz grains in Qs_1 may be weakly cemented together by iron compounds. Although Qs_1 overlaps in possible age ($32.0\pm2.8 - 24.0\pm2.1$ ka: Table 1A) with that of the possible age of the regional vadose calcrete forming-event (($27-22$ ka: Arakel and Wakelin-King (1991), Edgoose et al. (1993)), the indications are that Qs_1 was not affected by it, and therefore post-dates it. There is no contrast in loss on fusion (which may be used as a proxy for loss on ignition of carbonate, including any that might be present as cement) between Qs_1 and Qs_3, dated at $12.1\pm0.5 - 9.3\pm0.6$ ka (Table 1A).

The uncertainty in the luminescence dates of Qs_1 and Qs_3 is related to their history of the degree of saturation by water since their deposition, as outlined above. Qs_1 and Qs_3 of stratigraphic Pit 1 were deposited at the lake margin, rather than within it. The lake represents local base-level for shallow groundwater discharge, and during periods of lake highstand, the water table might have risen sufficiently to saturate Qs1 (and Qs_3) in Pit 1. However, nothing was observed to suggest that these sediments were covered and reworked by lake waters (e.g. sedimentary structures indicative of hydraulic working, or elevated ancient strandlines). If lake levels failed to reach such heights as to cover and saturate the sediments at Pit 1 for prolonged periods, younger rather than older ages for Qs_1 and Qs_3 seem more likely.

Member Qs_3 provides only a maximum age of the vertebrate fauna. As detailed below, the vertebrate fauna recovered from Qs_3 is characterised by fossorial animals, or those known to occupy burrows dug by other species, and/or animals that might have been taken as prey by animals that occupy burrows. Qs_3 is distinguished from Qs_2 only by its diagenetic features, particularly the presence of rhizoconcretions and the remains of vertebrates probably introduced post-depositionally. These features are indicative of the close proximity of a natural land surface. Qs_3 and Qs_2 occupy the same stratigraphic position with respect to overlying (Qs_4) and underlying (Qc) strata, and Qs_3 is simply a diagenetic facies (a soil by virtue of its pedogenic features, namely rhizoconcretions) of Qs_2 which developed below the natural surface. The lag of fossils and rhizoconcretions at Sites 1 and 2 is the product of deflation of all or most of Qs_3.

SYSTEMATIC PALAEONTOLOGY

More than 1000 cranial and postcranial specimens, representing an estimated minimum number of 125 individual animals ranging in size from small rodents to red kangaroos, were collected at Site 2. The Mygoora Local Fauna contains 12 species of vertebrates of which all but two are mammalian, as summarised in Table 2. Four taxa, Dasyurus geoffroii, Sarcophilus harrisii, Lasiorhinus sp. and Bettongia lesueur are now regionally extinct. Remains of two species of introduced mammals, the dingo, Canis familiaris, and the rabbit, Oryctolagus cuniculus, were present in the surface collections, but are distinguished from the Mygoora Local Fauna by their unmineralised state.

While the great majority of specimens were collected from the surface, some complete and partial articulated skeletons were found in situ and recovered by excavation, as described above. The surface collections consist of fragments of the most durable skeletal elements, only a few of which preserve articulation. Complete ankle joints of small macropodoids, sections of occluded upper and lower dentitions, and articulated vertebral segments support the observations that the primary deposition consisted of complete or partial carcasses.

The following species list is annotated with brief descriptions of the diagnostic material, and ecological and biogeographic notes abstracted from Strahan (1991) and Brown (1974), unless otherwise acknowledged.

Table 2. The Mygoora Local Fauna. Higher-level mammalian systematics follows Aplin and Archer (1987). † indicates species that became locally extinct in historical times, and †† indicates species that became locally extinct in prehistoric times.

Class Reptilia
  Order Squamata
    Suborder Sauria
      Family Varanidae
        Varanus sp.
    Suborder Ophidia
      Family Boidae
        ?Bothrochilus sp.
Class Mammalia
  Supercohort Marsupialia
    Order Dasyuromorphia
      Family Dasyuridae
        Dasycercus cristicauda
        Dasyurus geoffroii †
        Sarcophilus harrisii ††
    Order Peramelomorphia
      Family Thylacomyidae
        Macrotis lagotis †
    Order Diprotodontia
      Family Vombatidae
        Lasiorhinus sp.††
      Family Potoroidae
        Bettongia lesueur †
      Family Macropodidae
        Lagorchestes hirsutus †
        Macropus rufus
  Supercohort Placentalia
    Order Rodentia
      Family Muridae
        Notomys alexis
        Rattus villosissimus

Varanus sp. — monitor lizards

Small to medium-sized *Varanus* are represented by some mandible fragments and four vertebrae. While at least two individuals are present, the material is inadequate for specific determination (Fig. 5).

?Bothrochilus sp. — pythons

A short articulated vertebral series and isolated vertebrae indicate the presence of small pythons (Fig. 6) probably belonging to *Bothrochilus* (*B. childreni* group). Possibly more than one individual is represented as the elements were widely dispersed. Small to medium-sized pythons belonging to the *B. childreni* group are common elements in the present day central Australian fauna, preferring woodlands lining drainage systems and often sheltering in abandoned burrows.

Dasyurus geoffroii — western quoll

Western quolls are indicated by fragments of right and left dentaries with M_{1-3} and left maxillary M^{1-2} (Fig. 7A–B, G). Differences in the depths of the mandibles and molar wear on the specimens indicate a minimum of two individuals in the sample (Table 3). The western quoll is well adapted to arid conditions and until recently, lived in a wide range of habitats. The species is now confined to south-western Western Australia and Papua New Guinea and is probably extinct in inland Australia.

Dasycercus cristicauda — mulgara

The mulgara is the most abundant dasyurid in the Mygoora Local Fauna with a minimum of six individuals estimated from dentaries (Fig. 7C–F, H–I). Mulgaras prefer arid sandy habitats, living in burrows of varied complexity. At present mulgaras are common in the central Australian region of the Northern Territory.

Sarcophilus harrisii — Tasmanian devil

The Mygoora Lake *Sarcophilus harrisii* specimens (Fig. 8) provide the first record of Tasmanian devils within the central Australian part of the arid zone. A young individual is represented by upper checktooth rows and associated lower jaws recovered *in situ* (Fig. 8A–B). One or more mature individuals are also indicated by isolated upper and lower canines, a heavily worn left M^1 and an isolated, heavily worn right M_1 (Fig. 8C–F). The occluded, lightly worn dentition of the immature specimen includes upper and lower canines to M_3 and M^2 on the left, and upper and lower canines to M_2 and part of M^3 on the right. The presumably encrypted posterior molars have been lost.

Tasmanian devils have been recorded from numerous mainland Australian Quaternary sites, including one in the Top End of the Northern Territory (Calaby and White 1966), and are depicted in prehistoric Arnhem Land and Kimberley rock art (Calaby and Lewis 1977). Remains of Tasmanian devils in south-western Victoria
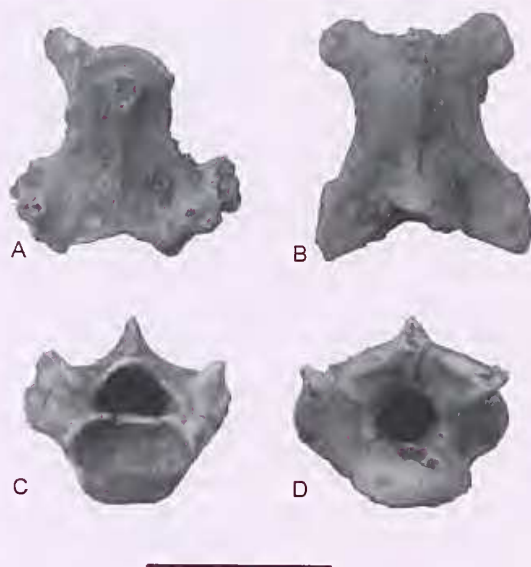

Fig. 5. Vertebra of *Varanus* sp., monitor lizard, Mygoora LF. **A**, ventral; **B**, dorsal; **C**, anterior; and **D**, posterior views. Scale bar = 1 cm.

Fig. 6. Vertebral series small python, *?Bothrochilus* sp. (ventral view, anterior to the left), Mygoora LF. Scale bar = 1 cm.

Table 3. Estimated minimum number of individuals (MNI) and relative abundance of mammalian species in the Mygoora LF.

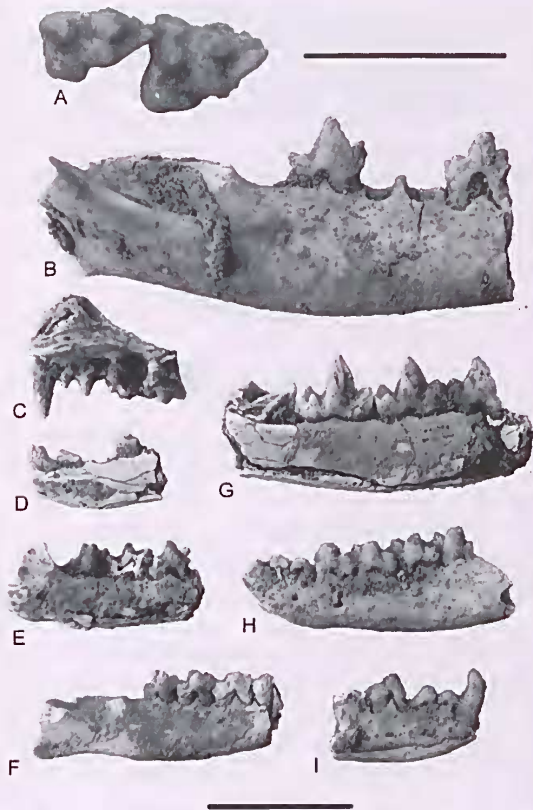| Species	MNI	Relative Abundance %
Dasycercus cristicauda	6	5.0
Dasyurus geoffroii	2	1.7
Sarcophilus harrisii	2	1.7
Macrotis lagotis	3	2.6
Lasiorhinus cf. *latifrons*	1	0.9
Bettongia lesueur	76	66.0
Lagorchestes hirsutus	15	13.0
Macropus rufus	1	0.9
Rattus villosissimus	6	5.0
Notomys alexis	4	3.0

Fig. 7. Selected specimens of Dasyuridae, Mygoora LF: **A**, left M^{1-2} of western quoll, *Dasyurus geoffroii*, enlarged, 1 cm scale to right; **B**, right dentary fragment of *Dasyurus geoffroii* with right M_2 and M_4; **C**, right maxilla of mulgara, *Dasycercus cristicauda* with C^1-M^2; **D**, right dentary fragment of *Dasycercus cristicauda* with $C-M_1$; **E**, right dentary of *Dasycercus cristicauda* with M_{2-4}; **F**, right dentary of *Dasycercus cristicauda* with M_{1-4}; **G**, left dentary of immature *Dasyurus geoffroii* with M_{1-4}; **H**, left dentary of *Dasycercus cristicauda* with $C-M_4$; **I**, right dentary fragment of *Dasycercus cristicauda* with $C-M_2$. Scale bars: A, 1cm; B–I, 1cm.

date to as recently as 600 years B.P. Though presently confined to the cool, temperate climate of Tasmania, *S. harrisii* occurred in semi-arid parts of western New South Wales and South Australia during the Pleistocene (Dawson 1982), and in the arid southern periphery of Western Australia (Baynes 1987). Length and width measurements of first and second molars from Mygoora Lake lie close to the regression lines for Late Pleistocene devils, and cluster with the smaller forms referred to *S. harrisii* (Fig. 9). The upper molars fall just slightly below the lower range for extant Tasmanian devils given in Dawson (1982), but their slightly narrower widths is attributed to the loss of the bases of the protocones where the teeth have been sheared off. Dimensions of the lower molars fall within the lower range for extant Tasmanian devils. The isolated, though incomplete molar crowns of the other Mygoora Lake devil specimens also correspond in width (within the

lower end of the range) and morphological details to extant Tasmanian devils.

Two, or possibly three Late Pleistocene size morphs (large, small and intermediate) of devils have been recorded from inadequately dated stratigraphic contexts in eastern and southern Australia (Dawson 1982). The largest morph, *Sarcophilus laniarius*, appears to represent a distinct population, while smaller morphs overlap with the lower ranges of molar dimensions of the extant Tasmanian devils and are not distinguishable from them on the basis of available data. The Mygoora Lake devils align with the smaller Pleistocene devils from Lakes Menindee, Garnpung and Tandou, New


Fig. 8. Associated and isolated teeth of *Sarcophilus harrisii*, Tasmanian devil, Mygoora LF: **A**, ventral aspect and **B**, dorsal aspect of upper and lower tooth rows of immature specimen; **C**, left lower canine and **D**, P_3; **E**, worn left M_1 and **F**, M^1; scale bar segments = 1 cm.

South Wales, and Dempsey Lakes, South Australia, all of which have recorded semi-arid to arid environments over the last 50,000 years or so of the Pleistocene.

Macrotis lagotis — bilby
The bilby is represented by three dentary fragments and six partial maxillary tooth rows (e.g. Fig. 10) indicating a minimum of three individuals. Once widespread over inland Australia, the range of the bilby rapidly contracted to scattered populations mainly north of the Tropic of Capricorn in the Northern Territory, western Queensland and east Pilbara and Great Sandy Desert in Western Australia in the early 20th Century. Bilbies prefer sandy or loamy substrates with little stone content in which they construct long, deep burrow systems.
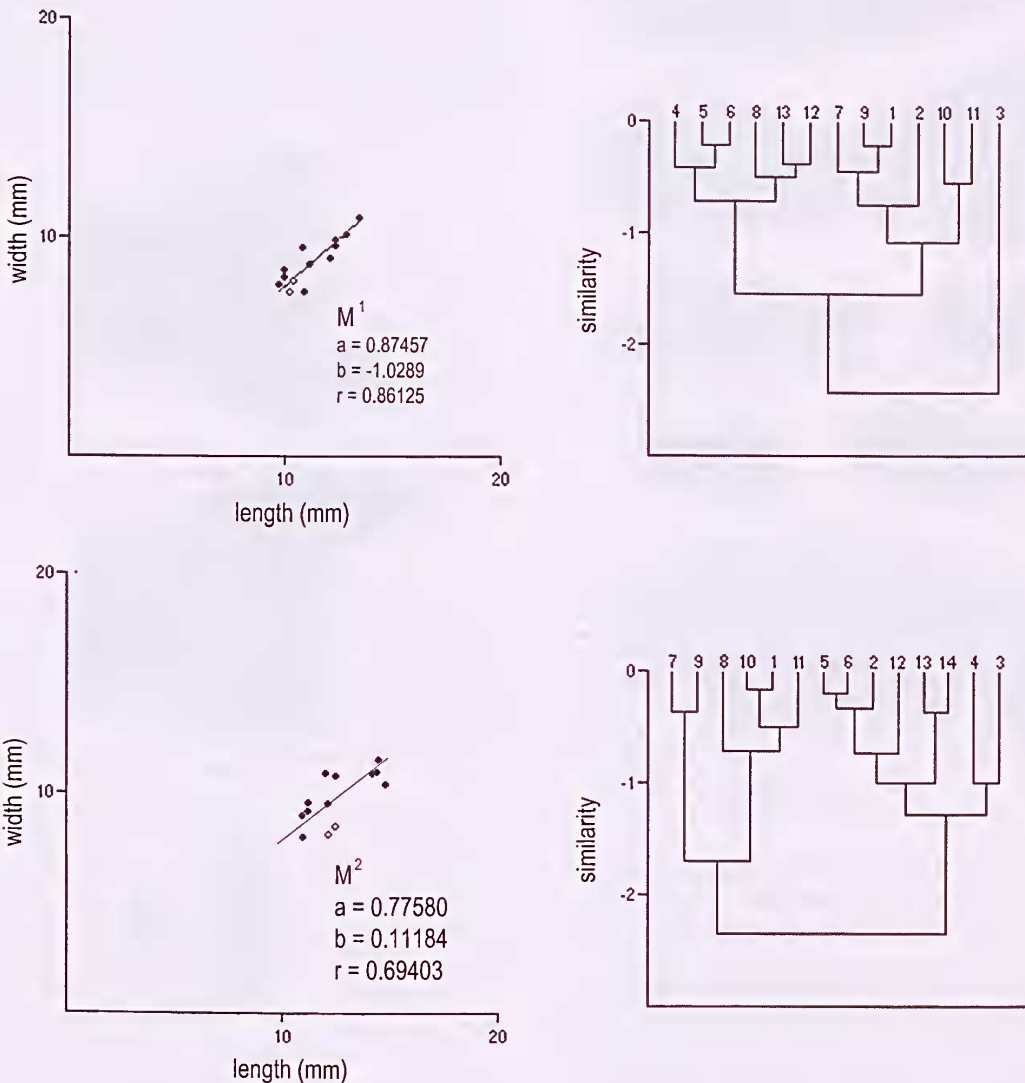
Fig. 9. Bivariate plots with fitted regression lines for length by width of late Pleistocene (solid circles) and Mygoora Lake *Sarcophilus* (open circles) specimens of M^1 (above) and M^2 (below). A clustering algorithm was applied to the variables, yielding a 'similarity tree' for localities, referred to by numerals: above (M^1), **1**, Marmor, Qld; **2**; Lake Tandou, NSW; **3**, Marmor, Qld; **4**, Dempseys Lake, SA; **5**, Mairs Cave, SA; **6**, Garnpung Lake, NSW; **7**, Cloggs Cave, (Buchan) NSW; **8**, Seton, (Kangaroo Island) SA; **9**, East Darling Downs, Qld; **10**, Cement Mills, Qld; **11**, Queenseliff, Vic.; **12**, Mygoora Lake, NT; **13**, Mygoora Lake, NT; Below: (M^2): **1**, Marmor, Qld; **2**, Lake Tandou, NSW; **3**, Dempseys Lake, SA; **4**, Dempseys Lake, SA; **5**, Mairs Cave, SA; **6**, Garnpung Lake, NSW; **7**, Seton, (Kangaroo Island) SA; **8**, East Darling Downs, Qld; **9**, Cement Mills, Qld; **10**, Cement Mills, Qld; **11**, Lancefield, Vic.; **12**, Queenseliff, Vic.; **13**, Mygoora Lake, NT; **14**, Mygoora Lake, NT. Mygoora Lake *Sarcophilus* measurements, especially the M^2, aligns them with Late Pleistocene semiarid inland lake localities (Lakes Tandou, Dempsey and Garnpung) and with localities associated with modern fauna only (Mairs Cave, SA; Queenseliff, Vic.). Data from Dawson (1982).

Fig. 10. Specimens of *Macrotis lagotis*, bilby: **A**, left M_{2-4}; **B**, right P^3-M^3. Scale bar = 1 cm.

Lasiorhinus sp. — hairy-nosed wombat

There are no previous records of hairy-nosed wombats in the Northern Territory. The specimens consist of left and right dentary fragments with complete left and right cheektooth rows, left and right lower incisors and a left upper incisor, probably all from one individual (Figs 11, 12). The specimens are indistinguishable from a range of material from the extant Blanchetown, South Australia, *Lasiorhinus latifrous* population used for comparison. The osteological distinction between the southern hairy-nosed wombat, *Lasiorhinus latifrons*, and the northern hairy-nosed wombat, *Lasiorhiuus krefftii*, is based on the length of the nasal bones relative to the frontals, features not preserved with the Mygoora Lake specimen; accordingly the present specimens are referred to only as *Lasiorhiuus* sp.

Southern hairy-nosed wombats are presently restricted to a narrow strip of semi-arid to arid habitat in southern South Australia with an annual rainfall of 200–500 mm, but has also been recorded in some cave deposits in the adjacent part of Western Australian (Baynes 1987). Northern hairy-nosed wombats survive as a small colony in southern Queensland but historic records indicate that the species ranged into Victoria and New South Wales. Remains of Late Pleistocene *Lasiorhiuus* have been found in several inland localities as well as Wellington Caves, where the genus was first recognised from fossil material.

Mitochondrial cytochrome-*b* DNA similarity analysis of wombat species indicates that the northern and southern hairy-nosed wombats "... are as closely related as other species known to hybridise in the wild" (Taylor *et al.* 1998). The northern hairy-nosed wombat population possesses 41% of the heterozygosity and 36% of the allelie diversity of a comparable sample of southern hairy-nosed wombats, suggesting that *Lasiorhinus krefftii* is a recent isolate of a larger
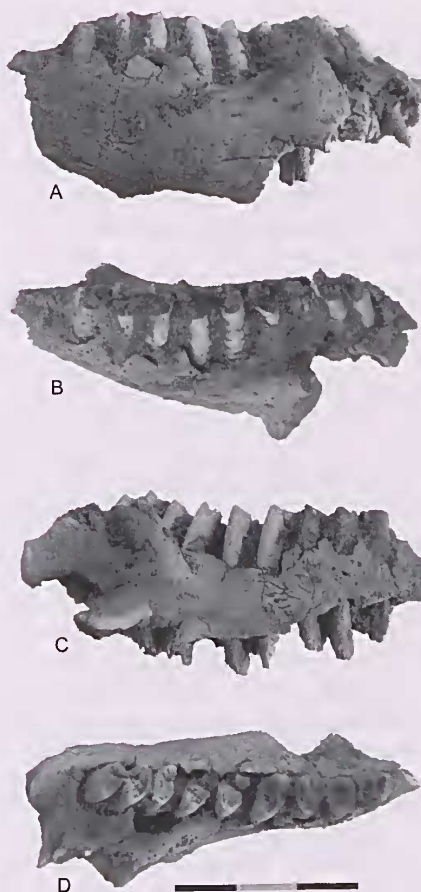

Fig. 11. Dentaries of *Lasiorhinus* sp., hairy-nosed wombat, Mygoora LF: **A**, lateral aspect of left dentary; **B**, occlusal aspect of left dentary; **C**, right lateral aspect of right dentary; **D**, occlusal aspect of right dentary. Scale bar intervals = 1 cm.

Fig. 12. Incisors of *Lasiorhinus* sp., Mygoora LF. A, medial view of right I^1; **B**, left I_1 in ventral view; **C**, same specimen as B in medial view. Scale bar = 1 cm.

population undergoing a progressive decline in genetic diversity. Dawson (1983) referred all of the Late Pleistocene Queensland and New South Wales hairy-nosed wombats to *Lasiorhinus krefftii*.

Hairy-nosed wombats are colonial and dig extensive, warren-like burrow systems. As sedentary populations, small, widely separated colonies have developed minor osteological and genetic distinctions since the end of the Pleistocene that have been given subspecific or specific status from time to time. None of these is currently recognised for either hairy-nosed wombat species (Dawson 1983).

Bettongia lesueur — burrowing bettong

The burrowing bettong (Figs 13, 14) is the most abundant species in the Mygoora LF with a minimum number of 76 individuals. A complete skull and most of the articulated postcranial skeleton of one individual was recovered by excavation. Once widely distributed and common in all states except Queensland and Tasmania, burrowing bettongs are extinct on mainland Australia, but survive on three small islands off the Western Australian coast. Burrowing bettongs are the only macropodoids that consistently occupy burrows throughout the year and construct extensive, complex and permanent warrens.

Lagorchestes hirsutus — rufous hare-wallaby or mala

Remains of rufous hare-wallabies (Fig. 15) are relatively common elements of the Mygoora LF. A sample of the more intact dentaries indicates a minimum

Fig. 14. *Bettongia lesueur*, burrowing bettong, Mygoora LF: A, skull and B, articulated pes. Scale bar intervals = 1 cm.

Fig. 13. Selected specimens of burrowing bettong, *Bettongia lesueur*, Mygoora LF: A, occlusal aspect of maxilla with left M^{1-3}; B, lateral aspect of right maxilla with P^3-M^{1-4}; C, lateral aspect of right dentary with P_3-M_{1-4}; D, medial aspect of left dentary with I_1-M_2; E, lateral aspect of left dentary with I_1-M_4. Scale bar = 1 cm.

Fig. 15. Specimens of mala, *Lagorchestes hirsutus*, Mygoora LF: A, medial aspect of left maxilla with M^{1-4}; B, occlusal aspect of right maxilla with M^{1-4}; C, occlusal aspect of right dentary with DP_3-M_3; D, lateral aspect of left dentary with P_3-M_4. Scale bar = 1 cm.

number of 15 individuals, though many small fragments and individual teeth suggest a larger number, as their crania and mandibles appear to have been less durable than those of *Bettongia lesueur*. Rufous hare-wallabies dig fairly deep burrows during the intense heat of summer, relying on shallower burrows or trenches during the cooler months. Drastic reduction of the once extensive range of *Lagorchestes hirsutus* appears to have followed a pattern similar to that of the burrowing bettong. Small populations survive on several small islands off the Western Australian coast, and attempts have been made to re-establish them in the Tanami Desert. Rufous hare-wallabies prefer semi-arid and arid sand plains with low, woody shrubs or spinifex hummock grasslands for shelter.

Macropus rufus — red kangaroo

The red kangaroo is represented by left DP_3, M_2, protolophid of M_3 and protoloph of left M^2 (Fig. 16). Though widely scattered over the surface collection area, these unworn check teeth can be accounted for as the remains of one immature individual.

Notomys alexis — spinifex hopping mouse

The spinifex hopping mouse is represented by dentary fragments and a maxilla (Fig. 17E, H, I), indicating a minimum number of 4 individuals. The species prefers sandy soils, especially stabilised sandhills into which they excavate deep, multi-entrance burrows. *Notomys alexis* is presently a common species in the central Australian region.

Rattus villosissimus — long-haired rat

Six individuals of the long-haired rat are represented by dentaries (Fig 17A–D, F–J). Long-haired rats dig shallow complex burrows. Populations of *R. villosissimus* are normally dispersed, but are subject to rapid build-up in favourable conditions.

Fig. 16. *Macropus rufus*, red kangaroo, Mygoora LF: **A**, left protolophid of M_4; **B**, left M_3. Scale bar = 1 cm.

Coprolites

Ellipsoidal aggregates of fragmented bone probably represent scats of devils and/or quolls. The illustrated example (Fig. 18) consists of remains of rodents and small macropodoids, but no species additional to those listed are identifiable.

GENERAL DISCUSSION

Except for the Tasmanian devil, all other Mygoora LF marsupial species are typical members of the arid, as opposed to the semi-arid, modern continental fauna (Brown 1974) (Fig. 19). Brown (1974) listed 27 species of arid zone marsupials, eight of which (30%) are represented at Mygoora Lake. Thirty-seven per cent of the total arid zone species are burrowers, whereas over 80% of the Mygoora LF sample consists of burrowing forms. Seventy-five per cent of the 20 arid zone species not present in the Mygoora LF are non-burrowing forms. Obviously the Mygoora LF depositional environment was highly selective for burrowing species, of which there are about three times as many in the arid zone fauna as there are in the semi-arid fauna (11%). Consequently, the probability of finding a semi-arid species, had any existed at Mygoora Lake during the depositional interval, is relatively low. On face value, the Mygoora LF represents a typical arid zone fauna adapted to xeric shrublands and tussock grassland within a mean annual precipitation regime of 250 mm or less.

The geographically nearest, comparable prehistoric vertebrate remains were collected from caves and rock crevices at Uluru and Kata Tjuta (Baynes and Baird 1992), located about 200 km west of Mygoora Lake. Attention is also drawn to the complementary works of Copley *et al.* (1989), who analysed bone in owl pellets or loose on the surface below owl roosts during the course of a mammal survey across northwestern South Australia, and Baynes and Johnson (1996). These studies establish which of the mammal species present in the Mygoora LF disappeared from the region in historical times. The large sample of nearly 17,000 mammal bones analysed by Baynes and Baird (1992) included remains of the short-beaked echidna, 22 species of marsupials, 12 species of microchiropteran bats, 10 rodent species and dingos, but the age or ages of these prehistoric assemblages have not been established.

The Uluru bones were accumulated primarily by barn owls (*Tyto alba*) with a small contribution from dingos. While a selective bias related to the size and predatory habits of owls is evident, the assemblage provides the most reliable sample of the Recent vertebrate community in the area at some time before the introduction by Europeans of cats, foxes, rabbits
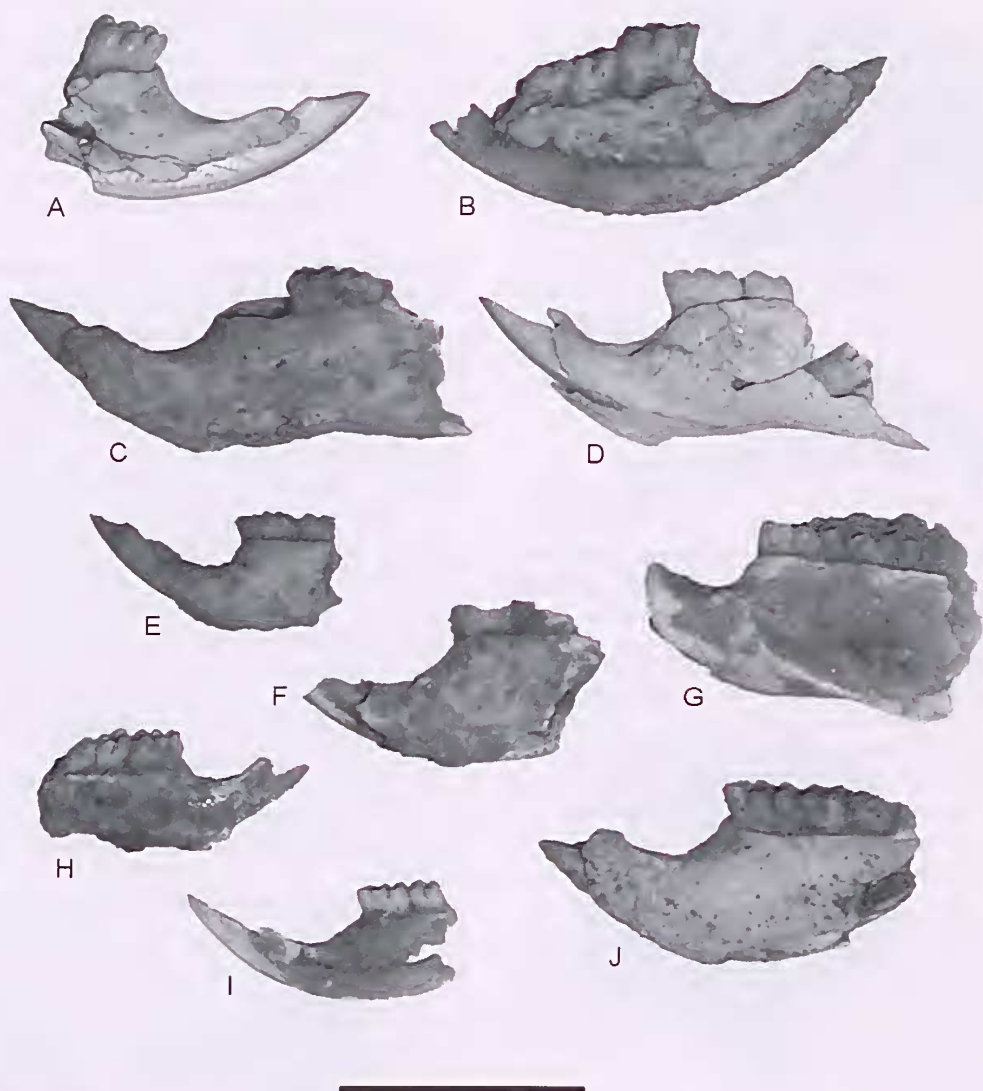
Fig. 17. Dentaries of murid rodents: **A–D**, **F**, **G** and **J**, dentaries of long-haired rat, *Rattus villosissimus*; **E**, **H–I**, dentaries of spinifex hopping mouse, *Notomys alexis*. Scale bar = 1 cm.
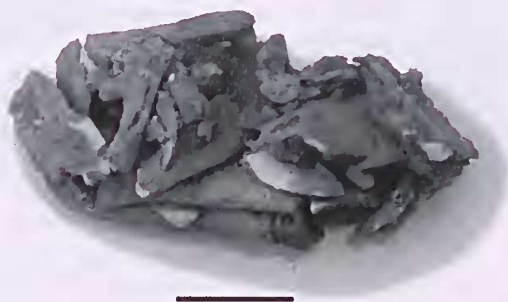

Fig. 18. Coprolite composed of rodent and small macropodoid bone fragments, Mygoora LF. Scale bar = 1 cm.

Fig. 19. Map delimiting semiarid and arid faunal zones of Australia, redrawn from Brown (1974); locations of Mygoora Lake and Holocene cave fauna from Uluru caves (Baynes and Baird 1992) are shown as triangles. Light grey tone shows the original (i.e. at about the time of European occupation of Australia) range of *Lasiorhinus latifrons*, slightly darker tone represents *Lasiorhinus krefftii* and the dark tone (Tasmania) represents *Sarcophilus harrisii* (after Strahan (1991)).

The Mygoora LF shows that the former range of the Tasmanian devil and hairy-nosed wombat extended well beyond present distributions. All other species are locally extant or have been recorded in the central Australian region since European contact (Copley *et al.* 1989; Baynes and Johnson 1996).

Cluster analysis of dental measurements groups the Mygoora Lake devils with inland Late Pleistocene devil populations from the Simpson Desert and western New South Wales lake regions (Fig. 9). Taking into account the previously known Late Pleistocene and Holocene distributions of *Sarcophilus* in semi-arid and arid palaeohabitats (Dawson 1982; Baynes 1987), the Mygoora LF represents a typical Eyrean vertebrate fauna, which if in any way unusual, is only for its lack of species diversity.

The Mygoora Lake *Lasiorhinus* sp. suggests the extent to which hairy-nosed wombat populations may have contracted during the Holocene. Because the Mygoora Lake environment is fairly typical of the region, it is possible that the range of *Lasiorhinus* extended at least 500 km further west along the Tropic of Capricorn.

The former presence of wombats at Mygoora Lake suggests that primary productivity may been somewhat

and grazing ungulates, subsequent to the earlier introduction of the dingo in the mid to late Holocene (Milham and Thompson 1976, Newsome and Coman 1989). Baynes and Baird (1992) identified 33 species of terrestrial mammals (excluding the dingo) compared to 10 from Mygoora Lake (Tables 4, 5). Differences are primarily in the number of smaller species of Muridae and Dasyuridae. Relative abundance (% minimum number of individuals for each species) is similar except for the much higher abundance of burrowing bettongs and malas at Mygoora Lake (Tables 3, 4), data that reflect the respective modes of accumulation at the two localities.

The Uluru assemblage is biased towards relatively small prey-items selected by owls, the Mygoora LF is biased towards species that exhibit fossorial behaviour or occupy borrows made by other animals. The sedimentological evidence indicates that the skeletal remains of such species, plus or including possible prey items selected by carnivores, accumulated within borrows in stabilised aeolian dunes. These dunes were subsequently remobilised, the more durable elements becoming locally concentrated by deflation. The Mygoora LF thus includes both articulated remains recovered by digging into undisturbed sediment, as well as more fragmentary material collected from the lag deposits at deflated surfaces.

Table 4. Comparison of relative abundance of species in Holocene Uluru cave deposits (Baynes and Baird 1992) with the Mygoora LF: X = approximately 0–1%; XX = 1–10%; XXX = 10–100% (categories from Baynes and Baird 1992).

Species	Uluru	Mygoora LF
Dasycercus cristicauda	XX	XX
Dasyurus geoffroii	X	X
Sarcophilus harrisii	—	X
Macrotis lagotis	X	X
Lasiorhinus sp.	—	X
Bettongia lesueur	X	XXX
Lagorchestes hirsutus	X	XXX
Macropus rufus	X	X
Rattus villosissimus	X	XX
Notomys alexis	XXX	XX

Table 5. Species representation in Holocene Uluru cave deposits (Baynes and Baird 1992) compared with the Mygoora LF.

Family	n species Uluru	n species Mygoora LF	Difference
Tachyglossidae	1	0	-1
Dasyuridae	10	3	-7
Peramelidae	3	0	-3
Thylacomyidae	1	1	0
Vombatidae	0	1	+1
Phalangeridae	1	0	-1
Potoroidae	1	1	0
Macropodidae	2	2	0
Muridae	10	2	-8
Canidae	1	0	-1

higher than in recent times, though no particular palaeoclimatic attributes can be inferred from these hardy and adaptable species. Southern hairy-nosed wombats live in parts of South Australia with little or no surface water and low mean annual rainfall. In contrast with the driest parts of their present range, the Erldunda lakes and Karinga Creek system are discharge zones for low salinity calcrete aquifers. Groundwater discharge sustains riparian vegetation even through long periods of drought, and this hydrogeological regime is one that preceded the accumulation of the Mygoora LF. Northern hairy-nosed wombats are also found in areas of high mean annual temperature, north of the Tropic of Capricorn in Queensland. Across their present range, hairy-nosed wombats are tolerant of extremes of temperature and aridity, so it seems unlikely that a hypothetical climate change in the direction of aridification could have been directly responsible for their extirpation in central Australia. Wombats co-exist today with dingos on mainland Australia, and with devils, and until recently also with the Tasmanian 'wolf', *Thylacinus cynocephalus*, on Tasmania, so there is no reason to suppose that their demise in central Australia was related to displacements amongst the carnivores. The reasons for the regional demise of wombats therefore appear to lie elsewhere, perhaps with increased fire frequency associated with human occupation of the continetal interior (e.g. Wasson 1989; Smith 1993).

The majority of vertebrate species in the Mygoora LF are burrowing forms that prefer stable or lightly consolidated, relatively deep, homogeneous sandy substrates. At present, the Mygoora Lake margins are spinifex-dominated mobile dunefields whose mobility is attributed primarily to a high frequency of wildfires throughout the Amadeus region. Frequent burning of arid shrubland drastically reduces local floral diversity and destabilises the soil (e.g. Wasson 1989), thus diminishing the available range of food plants and rendering the substrate unsuitable for burrow construction. Loss of vegetation would also have contributed to increased sediment yield, resulting in alluviation of drainages such as the Finke River system and comparable ones of the northern Simpson Desert, to the point that these rivers now terminate in floodout areas where runoff evaporates or dissipates into the desert sand. Expanding alluvial plains may have isolated colonies of wombats from each other. Should a local colony have failed, whatever the direct cause, recolonisation from other locales may not have been possible. Thus, frequent burning may have resulted in reduction and fragmentation of habitat suitable for wombats, to the point that they no longer occur over the central Australian massif.

CONCLUDING REMARKS

The Mygoora LF is dominated by fossorial animals, or those known to inhabit established burrows, and the sedimentological indications are that skeletal remains were preserved within burrows. Consequently, the age of the fauna post-dates its host stratum, determined by OSL dating to be between 12.1±0.5 – 9.3±0.6 ka. The lighter-coloured modern dunes, having been stripped off the fossiliferous unit and currently mobile in the environs of the fossil sites, were considered unsuitable prospects for TL dates that might usefully constrain the minumum age of the fossils, but the feasibility of radiocarbon dating the fossils themselves would be worth investigating. Burrowing by animals and formation of rhizoconcretions both imply that the aeolian dunes comprising the host unit were stable for a substantial period or periods of time, and that a significant hiatus occurred between stabilisation of the host sediments and coverage by remobilised sand.

The presence of Tasmanian devils and absence of dingos may indicate an earlier rather than later Holocene minumum age, and an earlier relative age than the prehistoric (but undated) assemblages from Uluru and Kata Tjuta described by Baynes and Baird (1992). On a balance of probabilites, we postulate a latest Pleistocene or early Holocene age for the Mygoora Local Fauna. The local extinction of *Sarcophilus* and *Lasiorhinus* is unlikely to have been due to climatic change. Tasmanian devils may have been displaced by the introduction of the dingo in the early to mid Holocene and the hairy-nosed wombat may have been extirpated by habitat fragmentation and degradation by an accelerated fire regime.

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